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FORUM SECTION

First Hand Witnesses of Sled Testing Over the Past Forty Years

Gordon Cress and Don McCauley

This editorial offers some insight into the growth of the sled testing industry from a couple of dinosaurs of the SAFE Association. In this most technologically advancing world we thought it might be a good thing to review what we have seen during our careers and where this aspect of the test community may be headed in the next decade or so. The US aerospace industry has been rocketing sleds down tracks from Lakehurst N.J. in the east, to Hurricane Mesa and Holloman AFB, and Edwards AFB and China Lake in the west for over sixty years. These tracks have provided fundamental insight into human tolerance, weaponry, and escape system performance not possible elsewhere. Unfortunately, many of these facilities are no longer operational, or are in danger of closure.

PR & F SNORT Sled Tracks. Photo US Navy

Many of us at SAFE have been involved personally with these facilities and their programs. Tests dealing with escape systems constitute only one part of track operations, but are the aspect with which the authors are acquainted. These tests were the pivotal proof of cockpit, canopy and canopy jettison systems, sequencing systems, ejection seat and escape path clearance designs intended for the protection of aircrew. Before a system was entered into service, it had to pass a rigorous series of 22 successively successful track tests. The authors were privileged to have been a part of many of the programs for researching, validating and qualifying escape and recovery systems. Some of these programs included the Gemini Spacecraft, the F-111, the F-15, F-18, F-105, the F-106, the T-38, the T-46A, the YF-22 and the F-22A for example.

Planning, preparation for, manning and the execution of these test programs has remained essentially the same throughout our lifetimes, while track operations and the data acquisition systems have matured significantly. In the beginning, it was common for the manufacturer's team to go onto the track, set or check camera settings, the placement of screen boxes, check the instrumentation and ballistics, and anything else associated with the test.

The track facilities have progressed to the point where their personnel are professional and expert at these tasks, and control all aspects of track operation. The contractor/manufacturer merely states his needs and objectives through a test plan/operations document, prepares his test article, and the track personnel do the rest. The need will always exist for facility/contractor interface, a test plan and procedure, and test item preparation via a checklist, and a post-test evaluation procedure.

In our day, instrumentation packages were carried on-board the sled as well as in the chest cavity of the test dummy. These provided data on sled acceleration, events such as system initiation, seat/canopy first motion, and seat distance vs. time up the rails; information that was not gathered during the flight of the seat: The early test dummy instrumentation packages commonly consisted of 8 to 12 channels of chest-mounted temperamental analog telemetry. The dummies (or manikins) were simple steel skeletons covered with rubber and had limited articulation. Available sizes were generally limited to five and ninety-five percentiles of the male flying population. Dummies were fitted with a chest cavity to accommodate the telemetry system and an antenna on the head under the helmet. We all prayed and hoped the antenna would not be blocked from the recording station as the dummy flew through the air during a test. The basic test data recorded during those early days consisted chiefly of tri-axial accelerations, rotation rates, one or two forces, and a few events. Batteries were wet cell types and the test dummies had to be kept generally in an upright position to reduce the chance of battery acid leakage.

As instrumentation came into the digital age and dummies became quite sophisticated, electronics technology came on-board and these systems gained more and more capability. The test team became heavy in personnel versed in electronics and data reduction. Those early data recording systems are a far cry from the sophisticated wireless, real time, and self-contained multi-channel systems now being used. Dummies as human analogues are coming on line that seem to feel and act nearly identically to humans.

Today's tests result in information on accelerations, rotations and a wide variety of forces and stresses applied to the test occupant and limbs from catapult ignition to touchdown. The test engineers have a much greater selection of manikin sizes available including the lighter weight representatives of the female flying population. More than 50 channels of information taken at thousands of samples per second may be obtained in any one test. Data from tests interact with computer models that predict human response to the test conditions with high accuracy. The link between data acquisition and the human response models is improving seemingly almost by the month. Some engineers are coming to feel that these sophisticated computer modeling systems are nearly as accurate as real test data and may have more application in that sled tests are limited to ground altitude and straight and level flight, whereas the computer analogs can simulate more closely the actual flight conditions. Sled and in-flight ejection tests are becoming of use more as a validation of the computer model rather as an end unto itself.

Photographic instrumentation was used to provide a visual record of the test and trajectory data. Photo instrumentation generally fell into four broad categories; tracking, sled-borne, fixed and trajectory. The tracking coverage ranged in camera speeds from 24 fps (nominal) to 400 frames per second and would provide a visual record of the test for analysis and evaluation of the system's performance. The tracking cameras and their operators were usually positioned along the track and anywhere from 500 to 1500 feet away from the track centerline. Each tracker was assigned a seat or dummy to concentrate on. However, the quality of the coverage depended on lens size and the experience and talent of the camera operator in those early days: - sometimes perhaps it also may have depended on what the operator did the night before … It wasn't all that unusual at film reviews to see the escape system exit the vehicle, then lots of blue sky, and finally see the test dummy under a parachute just about to touchdown. And THAT was sometimes seen after the cameraman searched the sky for what seemed like an endless time.

Current systems use sophisticated laser technology and automated tracking systems and so have much improved the coverage, and in turn the engineers' ability to analyze the system functions. High resolution video has eliminated waiting for hours or days to see the coverage. Radar guided cameras currently used at NASA can track flight test vehicles well beyond visual range - almost as though one is watching a show on TV.

Sled-borne cameras placed inside the cockpit and outside the fuselage, provided close up system performance coverage. Internal cameras were used at times to record the seat movement up the rails and as backup instrumentation. Outside cameras using periscope lenses or boom-mounted cameras, provided detail coverage of canopy jettison, canopy hinge action and/or relative close-ups of the system as it cleared the vehicle. These cameras could focus in on specific areas and components and document response to windblast in intricate detail. Fixed still image cameras were located along trackside to record close-ups of canopy jettison and escape system egress. The quality of data from these cameras likewise ranged from limited to very valuable. It was often an educated guess as to where to locate these cameras, and just when to trigger them. At times these photos were spectacular and decorate the walls of track offices and private albums. The misses are unseen.

Trajectories of the seats and dummies, and sometimes of the canopies, were determined in three axes by data obtained from the fixed trajectory metric cameras using triangulation calculations. This is now an automated process. Finally, there was documentary coverage used to record mundane test preparations, test article installation into the sled test vehicle and post-test results.

The track facilities provide the propulsion for the sled. Even before our time, sleds were often constructed in one piece. Propulsion was mounted on the same frame as the test vehicle. The propelling rocketry was usually taken from expired military solid rocket devices of various sorts. There were times when the aged propellant was cracked and an explosion would result. More than once we watched as rockets soared overhead and end over end across the sands. We learned to separate the pusher from the test vehicle: it saved so much repair work! Some test programs have used liquid propellant rockets, but the majority used the easier to handle solid motors. The test vehicles ranged from salvaged fuselages modified for track testing to sophisticated specially designed and manufactured vehicles.

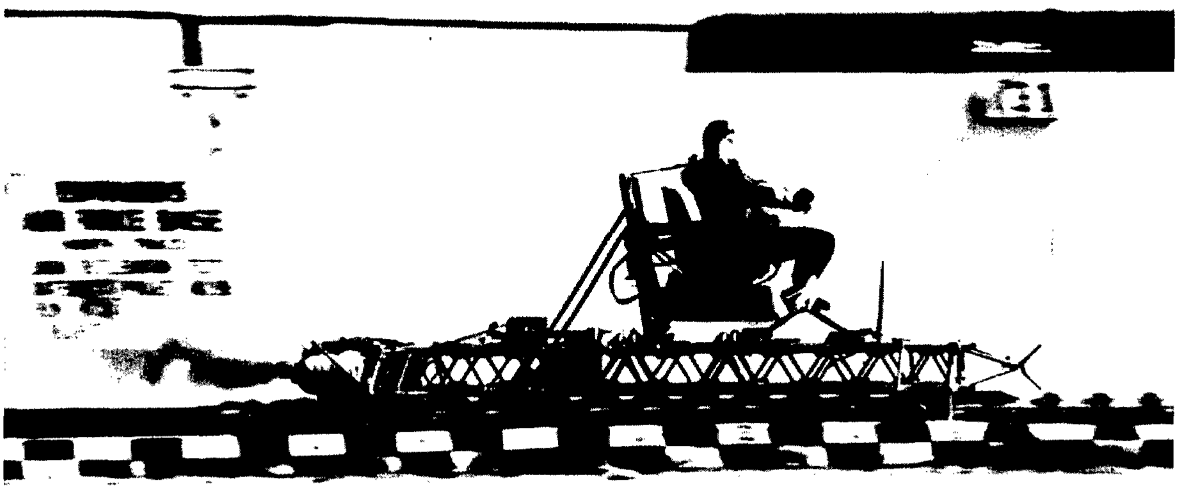
The early F-106 and F-105 programs are examples of the former while the F-22 program is an example of the latter. Today, there are only about three facilities available in the U.S. for dynamic ground testing of escape systems: government facilities at Holloman AFB in New Mexico and China Lake in California, and a privately owned Goodrich facility at Hurricane Mesa in Utah. In the last issue of this Journal this facility and its rich history was presented (Vol 33:1, 2005). Martin-Baker operates its own private facility in Northern Ireland.

As budgets remain depressed year after year, and under the lure of advancing human analog computer systems, the sled test will increasingly come under scrutiny as the primary means for flight certification and safety analysis. Some say they are too expensive. Some say the advances in computer control, dynamic high speed biomodels and trajectory analysis will eclipse the "old fashioned" sled test. For those of us that have seen the evolution, perhaps even participated in it, that "have been there" and are now fading away into retirement, we offer a simple word of caution.

Until we reach the point where all human operators of military tactical aircraft fly RPV's from easy chairs, there can be nothing more important than validating the dynamics of escape path clearance, learning, demonstrating and qualifying system performance through firsthand observation with sights, sounds and smells i.e. TESTS.

There is no substitute to getting up before dawn, freezing in the desert wind while the instrumentation folks go through their endless checks and tests, and watching those pusher rockets go off and seeing the parachutes in the distance – sometimes. Because hardware has a way of surprising you!

The legacy we leave to the new generation is to embrace the new, but remember the past. Feel the test, AND hear the results of the computer analyses. It is only through such experiences one can truly tell a pilot, "That system is safe. You can bet your life on it!"



Lt. Col. John Stapp on the rocket sled at Edwards Air Force Base.